Contextual factors and spatial patterns of childhood malnutrition in provinces of Burkina Faso

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Abstract

Background

Approximately 45% of all children's deaths are associated with malnutrition, and sub-Saharan Africa is hardest hit by this phenomenon. However, information on geographical variations of malnutrition in developing countries is limited. This study examined the geographical distribution and community characteristics associated with child malnutrition in Burkina Faso.

Design

Data from the 2011 Burkina Faso Demographic Health Survey were analyzed. A general Kriging interpolation method was used to generate spatial malnutrition patterns. The global Moran's I test was used to identify significant malnutrition spatial patterns. Generalized estimating equations (GEEs) were fitted to examine the association between community level factors and malnutrition.

Results

Average rates of stunting and wasting in the communities were 32.48% and 15.05%, respectively. Stunting hotspots were observed in the eastern and northeastern parts of Burkina Faso (i.e., Oudolan, Séno, and Yagha, among others), while high rates of wasting were observed in the north-central part. The GEE results revealed lower stunting rates in communities with a higher percentage of households with improved sanitation. Communities with higher rates of professionally assisted births were associated with low wasting rates, while communities with higher rates of households with a low wealth index reported higher rates of wasting.

Conclusions

Spatial statistical models of malnutrition prevalence are useful for indicating hotspots over wide areas and hence, for guiding intervention strategies. This study revealed significant geographical patterns and community factors associated with childhood malnutrition. These factors should be considered in future programs aimed at reducing malnutrition in Burkina Faso.

Keywords

malnutrition, spatial analysis, generalized estimation equation, Burkina Faso

Introduction

Child malnutrition continues to be a major health concern around the world.[1] Globally in 2012, approximately 165 million children under 5 years of age were stunted, 99 million were underweight, and 51 million exhibited wasting [2]. The burden is more prominent in low-income countries particularly in sub-Saharan Africa where the prevalence of malnutrition was reported to be approximately 33% [3]. In the case of Burkina Faso, a relatively higher rate of child chronic malnutrition (31.1%) was reported compared to acute malnutrition (8.2%) [3].

Factors associated with child malnutrition were reported to be multidimensional and interrelated, encompassing individual-, household-, and community-level factors [4]. Nevertheless, programs that focus on child malnutrition interventions mostly emphasize the importance of individual-level and household-level factors (e.g., childcare practices, family income, and mother’s education) [5, 6]. Recently, a few studies began paying attention to community-level factors associated with childhood malnutrition in low-income countries. A study in Botswana revealed that 17% of the variation in the nutritional status of under-five children was due to differences between communities [7]. Another study in Cameroon found that community environmental factors, such as the proportion of households with access to water and sanitation in each cluster, had beneficial effects on a child’s nutritional status.[8] Those studies pointed to the importance of community infrastructure in reducing childhood malnutrition.

Alternatively, geographical location may be a proxy of community and environmental factors that influence malnutrition. The geographical distributions of health service provision, community socioeconomic status, and community norms regarding children feeding practices may be associated with childhood malnutrition [9]. Using a geographic information system (GIS) and spatial regression models, researchers were able to identify hotspots for health outcomes to ensure cost-effective targeted interventions [10].

Previous studies demonstrated geographical patterns for health outcomes in children. For instance, a Malawian study revealed that the distribution of children's diarrhea was mostly concentrated in the central districts, while childhood fever displayed a strong north-south gradient in district spatial effects [11]. A previous study on malnutrition in Burkina Faso focused on examining individual-level factors [12]. At present, geographic variability in child malnutrition in low-income countries, including Burkina Faso, is poorly understood [3]. Therefore, this study aimed to explore the geographical distribution of child malnutrition and examine community characteristics associated with children's stunting, wasting, and being underweight in Burkina Faso. Findings from this research may assist in devising targeted interventions for reducing childhood malnutrition.

Methods

Data

Data came from the 2010 Burkina Faso Demographic and Health Survey (BFDHS), conducted between April 2010 and January 2011. The 2010 BFDHS provides nationally and regionally representative data on measures of population health, socioeconomic, demographic, environmental, immunization, anthropometric, and other child health indicators. This survey employed a two-stage stratified sampling design. The sampling design randomly selected clusters

(Zones de'nombrement) by probability proportional to their size. The cluster is the smallest census unit with an average population of 1000 in rural areas and 1200 in urban areas. The second stage was to randomly select clusters of households in each cluster. Interpersonal interviews were conducted using a structured questionnaire. Geographic coordinates of community centroids were also collected. For privacy purposes, these geographic coordinates were randomly displaced by 5 km in rural areas and 2 km in urban areas. Representative samples of 572 clusters and 6120 children under the age of 5 years were included in the survey. Only children under the age of 5 years whose height and weight measurements were available were included in this study. The number of respondents in each community ranged from 14 to 53 Individuals with an average of 30 individuals per community.

Measures

Outcome Variables

Both outcomes and explanatory measures were constructed by aggregating individual-level data to the cluster level. Outcomes of this study were rates of a malnutrition status, including stunting and wasting, among children less than 5 years of age. Children with a Z score of <-2, relative to World Health Organization (WHO) standards, in height-for-age or weight-for-height were categorized as stunted or wasted, respectively [13]. Each outcome measures a different aspect of the nutritional status with stunting representing chronic undernutrition and wasting representing acute undernutrition.

Explanatory Variables

The first domain of explanatory variables measured health service utilization and the local public health infrastructure, including community skilled birth attendance, and communities with access to improved water, improved sanitation, and immunization coverage. Community skilled birth attendance was defined as the percentage of women aged 15~49 years who had used skilled birth attendants (skilled birth attendance included births assisted by doctors, midwives, or trained birth attendants) [14]. Improved water sources include piped water into dwellings, piped water to yards/plots, a public tap, standpipe, tube well, or borehole, a protected dug well, a protected spring, and rainwater. Improved sanitation types included flush toilets, a piped sewer system, septic tanks, flush/pour flush to pit latrines, ventilated improved pit latrines, pit latrines with a slab, composting toilets, and others. These categorizations were based on the recommendation of the WHO and United Nations Children's Fund (UNICEF) [15]. Immunization coverage was measured by the percentage of children aged 12~23 months who had received one dose of measles vaccine.

The second domain of explanatory variables measured the community-level socioeconomic status, including the community wealth status and women's literacy. The community wealth status was defined as the percentage of households in the lowest 20% of the wealth index. The wealth index is a composite score measured by household assets, such as televisions, bicycles, materials used for house construction, and other characteristics related to the wealth status. Scores of household assets were generated through a principal component analysis and then were standardized and categorized into quintiles [14]. Women's literacy rates were defined as the percentage of women aged 15~49 years who are literate.

Prevalence rates of malaria and anemia among children under 5 years of age were included in the analyses because prior studies suggested their relevance to child malnutrition rates in low-income countries [16]. We also measured the percentage of agricultural land cover within 25 km of each household cluster using 2005 GlobCover data. Agricultural land cover was classified using the United Nations Land Cover Classification System [17]. The distance of a community centroid to the nearest road was measured to represent the accessibility to food resources, since this factor will likely affect transportation costs for purchasing food and for the household's access to health and nutrition information [18].

Statistical Analysis

We used ArcGIS (ESRI, Redlands, CA, USA) to create maps and conduct analyses of spatial patterns according to Tatem et al.,[19] and global Moran's I to examine spatial autocorrelations [20].

The geographic information system (GIS) ArcGIS (vers. 9.3, ESRI) was used for the spatial analysis. Smoothed maps of spatial patterns by different child malnutrition outcomes were created in GIS using a general Kriging interpolation method (ordinary Kriging), an algorithm which uses nearby values to predict prevalences in unmeasured locations.[21] Then we used global Moran's I to test for a significant pattern of spatial autocorrelation with child malnutrition at the community level in Burkina Faso [22] A statistically significant positive value for Moran's I is a sign that communities with similar child malnutrition scores are higher or lower than the scores in neighboring communities [21]. Since the global Moran's I does not identify individual clusters, we further used the Local Indicator of Spatial Autocorrelation (LISA) to identify particular communities clustered with high and low child malnutrition scores. Specifically, LISA was used to identify significant communities where both the target community and its neighbors had high values (high-high/hot spots) or both had low values (low-low/cold spots).

We used a two-step procedure that combined generalized estimating equation (GEE) models and spatial modeling techniques in our analyses by first constructing a cluster-level child malnutrition measure that was adjusted for potentially confounding effects of individual-level covariates. Individual-level covariates for which we adjusted included child's gender, age of the child, maternal age, mother's educational level, the household wealth index, ethnicity, size at birth, and number of under-five children in the household. GEE models were constructed for controlling correlated observations within clusters. Second, we derived the adjusted cluster-level child malnutrition score from the GEE models and then regressed this score onto cluster-level explanatory variables. In this second step, we compared both the ordinary least square models and spatial lag models. Spatial lag models were estimated through an autoregressive process in the dependent variable with the following equation:

$$Y=\rho WY+X\beta+\varepsilon;$$

where ρ is the spatial autoregressive parameter, W is a weighted matrix that expresses a form of spatial associations among each pair of clusters, X is a matrix of exogenous explanatory variables with an associated vector of regression coefficients, and ε is a vector of normally distributed random error terms.

The fitness of the model was assessed using the quasi-likelihood information criterion (QIC). A variance inflation factor (VIF) was used to check for multicollinearity in the model. The significance level of alpha was set to 5%. All of the analyses were carried out using SAS 9.4 statistical software (SAS Institute, Cary, NC, USA).

Ethical considerations

The protocol for the BFDHS was reviewed and approved by the Burkina Faso National Ethics Committees for Health Research, the Institutional Review Board of ICF International, and the Centers for Disease Control and Prevention in Atlanta, GA, USA. All participants provided informed consent to the BFDHS surveyors at the start of each individual interview. The Burkina Faso DHS datasets are publicly available, and clearance to analyze them was provided by the International Classification of Functioning Disability and Health (ICF) under the DHS program [23].

Results

Table 1 lists descriptions of the three child malnutrition outcomes and other explanatory variables at the community level. Average rates of stunting and wasting in communities were 32.48%, and 15.05%, respectively. Anemia and malaria were also quite high among children at 87.35% and 59.79%. Measles vaccination, professionally assisted birth, and improved water supply were all quite high at 87.88%, 74.68%, and 79.46%, respectively.

Figure 1 displays the level of malnutrition based on adjusted scores of stunting and wasting using a general Kriging interpolation method. High rates of stunting were observed in Oudolan, Séno, Yagha, Tapoa, Namantenga, Loba, and Comoé Provinces, while high rates of wasting were seen in Yatenga, Bam, and Zoundwéogo. Similar results were observed in Figure 2, in which the local Moran's I statistics show hot spots (concentrations of high rates) and cold spots (concentrations of low rates). Hot spots of stunting were in the eastern, northeastern, and portions of the southwestern parts, while cold spots were in central areas (Namatenga, Oubritenga, Kadiogo, Bam, and Bazèga Provinces). In contrast, wasting hot spots were in provinces such as Bam, Yatenga, and Passoré in the north-central part.

Table 2 summarizes results from the ordinary least squares (OLS) and the spatial lag models for child malnutrition rates. A significant Moran's I in the OLS models indicated that communities would also have higher expected prevalence rates if the adjacent communities have higher prevalence rates. The disappearance of significant Moran's I statistics in the spatial lag models suggested that there was no significant spatial autocorrelation left in the residuals. Overall, the spatial lag models seemed more appropriate in predicting the outcome, indicating influences from neighboring communities. The spatial lag models explained 36.9% and 16.7% of variations in the rates of stunting and wasting, respectively, higher than the 28.9% and 11.2% explained by the OLS models. According to the spatial lag models, communities that had a higher percentage of households with improved sanitation (β=-0.0008) were associated with lower stunting rates. Regarding wasting, communities that had a higher rate of professionally assisted births (β=-0.0002) were associated with a lower rate of wasting, while communities that had a higher rate of households with low wealth status (β=0.0003) were associated with a higher rate of wasting.

Discussion

This is one of the few research studies that used GIS data to identify factors associated with children's malnutrition, and is the first study to do so in Burkina Faso, a country which has had some of the highest rates of childhood stunting and wasting [3]. Results indicated that the use of a spatial lag model was more appropriate than the OLS model in predicting rates of stunting and wasting at the community level. The use of spatial lag modeling can adjust for influences of certain factors, such as famine, drought, or traditional feeding practices, which can impact a wide region, rather than just a community. It reaffirms previous findings that children's malnutrition does not occur at random, but tends to be concentrated in certain areas, and shows significant correlations with adjacent communities [24].

Results of this study revealed that child malnutrition in Burkina Faso remains significantly high, as previously reported [3]. Moreover, this research identified areas that were in greater need of interventions. Higher stunting prevalences were found in northern and eastern parts. Regional factors, such as adverse effects of weather on agricultural harvests, likely significantly impact children's nutritional status [25]. Crop production was associated with a poorer nutritional status in children in a rural farming population in northern and eastern regions of Burkina Faso [25]. The western region has favorable conditions for agriculture and is a cereal-surplus area. In contrast, the eastern and northern parts of Burkina Faso are less suitable for agricultural development -- the former is limited by poor soils and the latter by its low rainfall patterns [26]. These areas have been identified as the most structurally vulnerable regions of Burkina Faso [27]. Hence, children in these areas are expected to be more susceptible to food insecurity than their counterparts in central and western areas. In terms of wasting, high wasting prevalence rates were concentrated in a few provinces such as Yatenga, Bam, and Passore in the north-central area. These provinces are known to have severe crop pests [28].

This research also identified significant community-level factors that may be associated with stunting and wasting. Our analysis revealed that communities with improved sanitation had a lower level of stunting. Previous studies indicated that poor sanitation might have a negative impact on the nutritional status of children by increasing the probability of diarrhea [29] and intestinal worm infections [30]. These infections and conditions can directly affect the nutritional status through loss of appetite, maldigestion, and other pathways. Moreover, frequent intestinal infections may lead to environmental enteropathy [31], a condition characterized by the poor absorption of food, vitamins, and minerals. Contrary to the negative acute impacts of diarrheal episodes, it is not easy to recover from the chronic effects of environmental enteropathy [32], and thus chronic malnutrition and subsequent growth stunting can result [33], Furthermore, environmental enteropathy was hypothesized to be one of the causes of a reduced protective effect of oral vaccines administered to children, resulting in higher risks of infectious diseases and nutritional deficiencies [34].

Socioeconomic inequality in wasting among children under five has been frequently reported [35]. Communities with a high percentage of low-income families would more likely be an economically disadvantaged community with little capacity to deal with acute and sudden onset of food shortages [36]. In this research, communities with a low percentage of skilled attendants to assist births were more likely to have a higher rate of wasting, as well. The low percentage of assisted births was probably an indication of deprived access to basic health care, particularly prenatal care. It is likely that such communities will not have the necessary medical resources or manpower to provide care for children when needed.

To sum up, improvements in the economic situation, healthcare infrastructure, and hygiene facilities have played important roles in combating childhood malnutrition. Based on findings from this research, their importance seemed to exceed other factors such as malaria, anemia, or mother's education, in the case of Burkina Faso. Other countries will likely exhibit different patterns since each individual country faces unique environmental challenges. This study has several limitations. First, the results cannot be generalized at the individual level since it was based on community-level data. Second, the selection of indicators was limited by the availability of data and hence, the research may have excluded some relevant variables previously identified to be associated with childhood malnutrition [3]. Third, this was a cross-sectional study, and therefore, the causal relationship between community-level variables and malnutrition should be interpreted with caution.

Conclusions

Childhood stunting and wasting did not occur randomly in Burkina Faso. Hot spots for stunting were found in northern and eastern regions, while hot spots for wasting were found in a few provinces such as Yatenga, Bam, and Passore in the northwest-central region. Intervention efforts should first concentrate on regions identified as hot spots. Efforts to reduce children's malnutrition should incorporate multiple approaches, including reducing poverty, strengthening basic healthcare infrastructure, and improving sanitation practices.

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Competing interests: None declared.

Ethics approval: The protocol for this study was reviewed and approved by the Burkina Faso National Ethics Committees for Health Research, the Institutional Review Board of ICF International, and the Centers for Disease Control and Prevention in Atlanta, GA, USA. Informed consent was sought from respondents at the beginning of the interview. The Burkina Faso DHS datasets are publicly available, and clearance to analyze them was provided by the International Classification of Functioning Disability and Health (ICF) under the DHS program.

Data sharing statement: The study used, with permission, data from the 2011 Burkina Faso Demographic and Health Survey. The data are publicly available and may be requested at https://dhsprogram.com/data/available-datasets.cfm.

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Table 1 Description of Main Variables

	Mean	SD
Child stunting (%)	32.48	19.04
Child wasting (%)	15.05	15.02
Child anemia (%)	87.35	14.73
Women’s literacy (%)	24.42	22.22
Child malaria (%)	59.79	28.40
Child measles vaccine coverage rate (%)	87.88	21.22
Professional assisted birth (%)	74.68	28.58
Improved sanitation (%)	33.33	35.38
Improved water (%)	79.46	25.35
Low community wealth (%)	18.02	19.90
Land cover rate (%)	74.78	27.23
Distance to the main road (m)	2765.94	3165.93

SD, standard deviation

Table 2 Multivariate analysis of socioeconomic factors on childhood malnutrition

	Stunting				Wasting			
	OLS		Spatial lag		OLS		Spatial lag	
	Coefficient	(SE)	Coefficient	(SE)	Coefficient	(SE)	Coefficient	(SE)
Children anemia	0.00029	(0.00023)	0.00018	(0.00022)	0.00027*	(0.00013)	0.00021	(0.00013)
Women’s literacy	-0.00015	(0.00024)	-0.00023	(0.00023)	-0.00016	(0.00013)	-0.00018	(0.00013)
Child malaria	0.00006	(0.00017)	0.00002	(0.00016)	-0.00008	(0.00009)	-0.00006	(0.00009)
Child measles vaccine coverage	-0.00036*	(0.00015)	-0.00027	(0.00015)	0.00003	(0.00009)	0.00007	(0.00008)
Community skilled birth attendance	-0.00023	(0.00017)	-0.00019	(0.00016)	-0.00025**	(0.00010)	-0.00021*	(0.00009)
Improved sanitation type	-0.00100***	(0.00018)	-0.00081***	(0.00017)	-0.00009	(0.00010)	-0.00007	(0.00010)
Improved water source	-0.00011	(0.00016)	-0.00006	(0.00015)	0.00010	(0.00009)	0.00006	(0.00009)
Low community wealth	0.00010	(0.00026)	-0.00002	(0.00024)	0.00043**	(0.00014)	0.00031*	(0.00014)
Agriculture land cover	-0.00029*	(0.00014)	-0.000105	(0.00014)	0.00000	(0.00008)	0.000016	(0.00008)

Distance to main road	-0.000001	(0.00000)	0.000000	(0.000001)	-0.000002**	(0.00000)	-0.000001	(0.00001)
Lag			0.43433***	(0.06494)			0.36027***	(0.08050)
R	0.289132		0.369305		0.111891		0.167265	
Moran's I	0.07906***	(0.0158)	-0.01924	(0.0153)	0.0688***	(0.0153)	-0.01924	(0.0158)

*p<.05; **p<.01; ***p<.001, OLS, ordinary least squares, SE, standard error

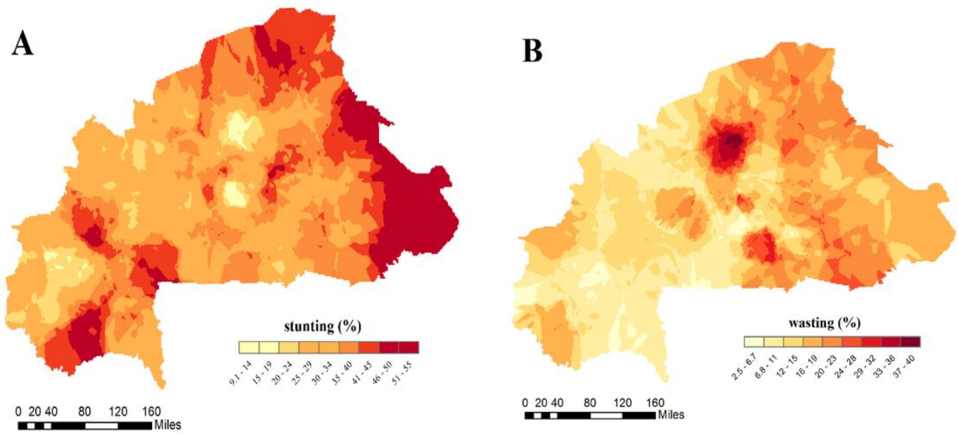

Figure 1. A, Stunting patterns in provinces of Burkina Faso. B, Wasting patterns in provinces of Burkina Faso

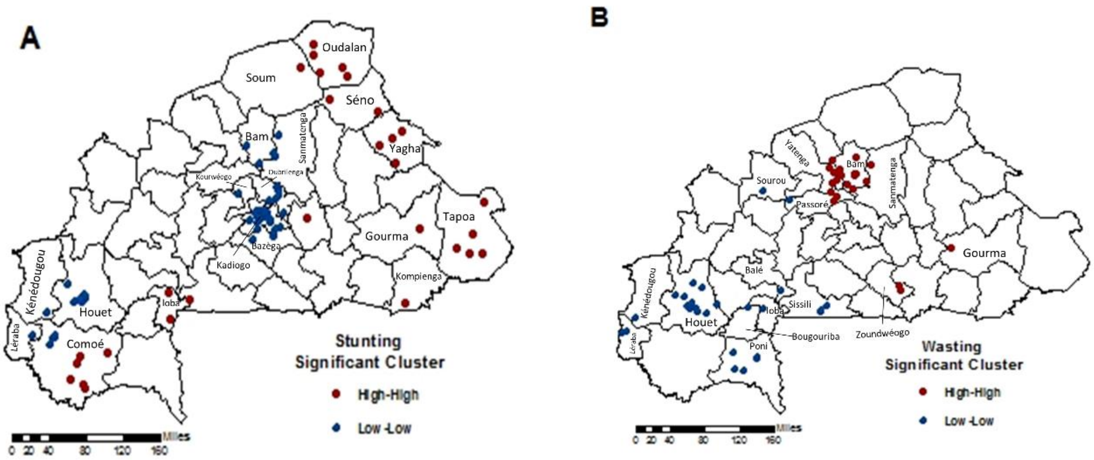

Figure 2 A, Significant stunting patterns in provinces of Burkina Faso derived from the Moran’s I test. B, Significant wasting patterns in provinces of Burkina Faso tested by Moran’s I test.